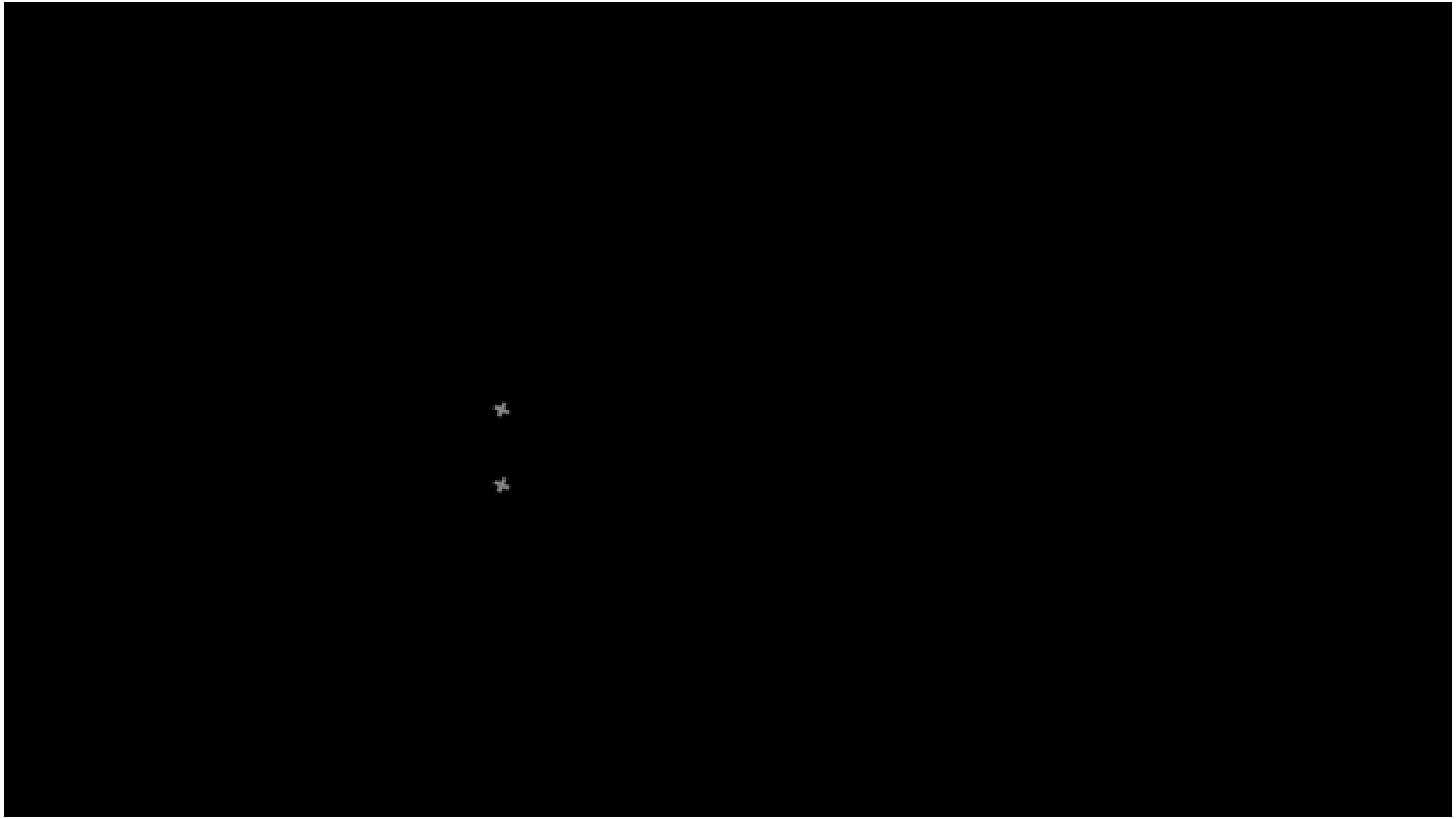
Welding as a joining process

https://www.youtube.com/watch?v=bkwpNs30qDo



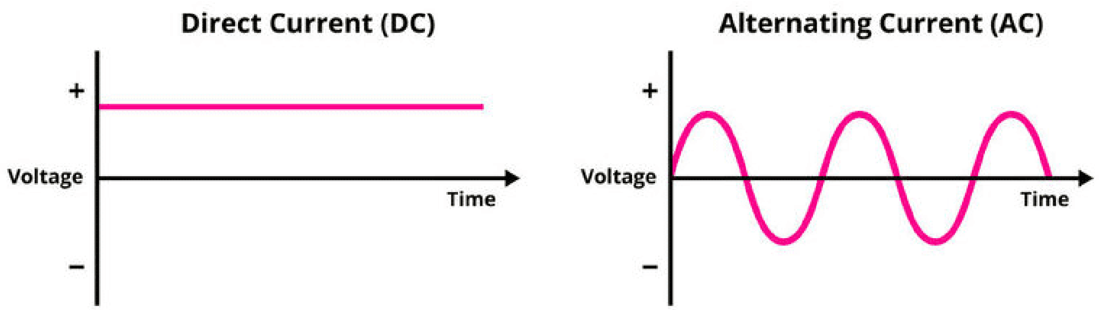
Welding as a joining process

A process of joining two or more then two metals or alloys with or without the application of filler rod, pressure, heat.

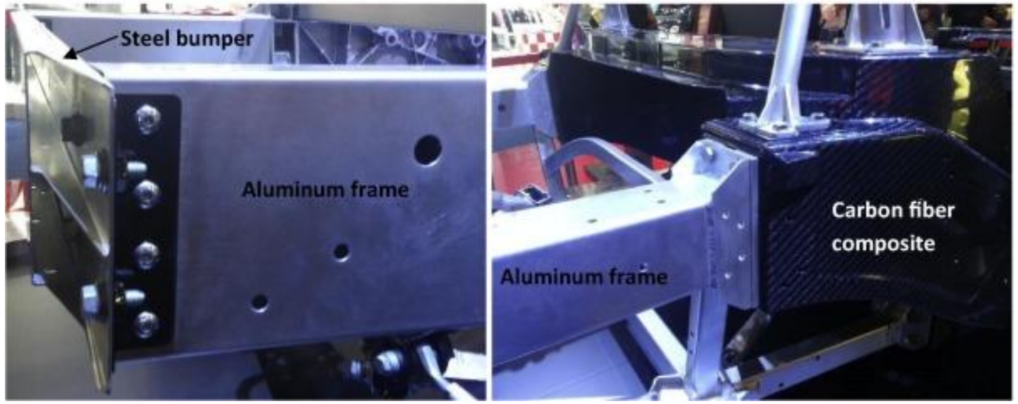
Joint is made by bringing surfaces of metals close enough *(by heat)* to form atomic bond.

The key to all welding is atomic-level inter-diffusion between the materials being joined, whether that diffusion occurs in the *liquid, solid, or mixed state.*

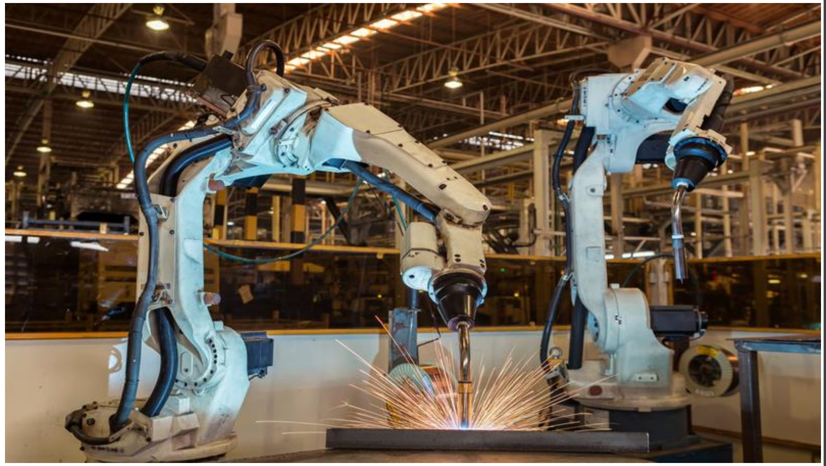
- Source of heat for fusing metal can be *gas, electric current (DC and AC),* laser, plasma or chemical.
- Process is applied to metals, polymers, ceramics, composites and glass.



Application of Welding



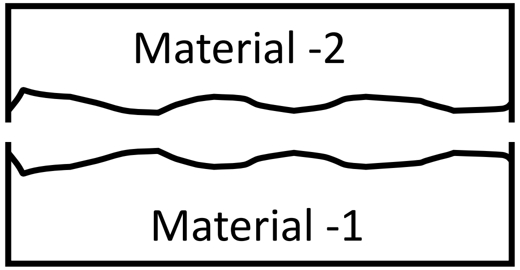
Application of Welding

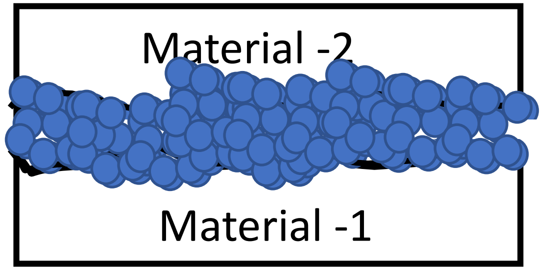


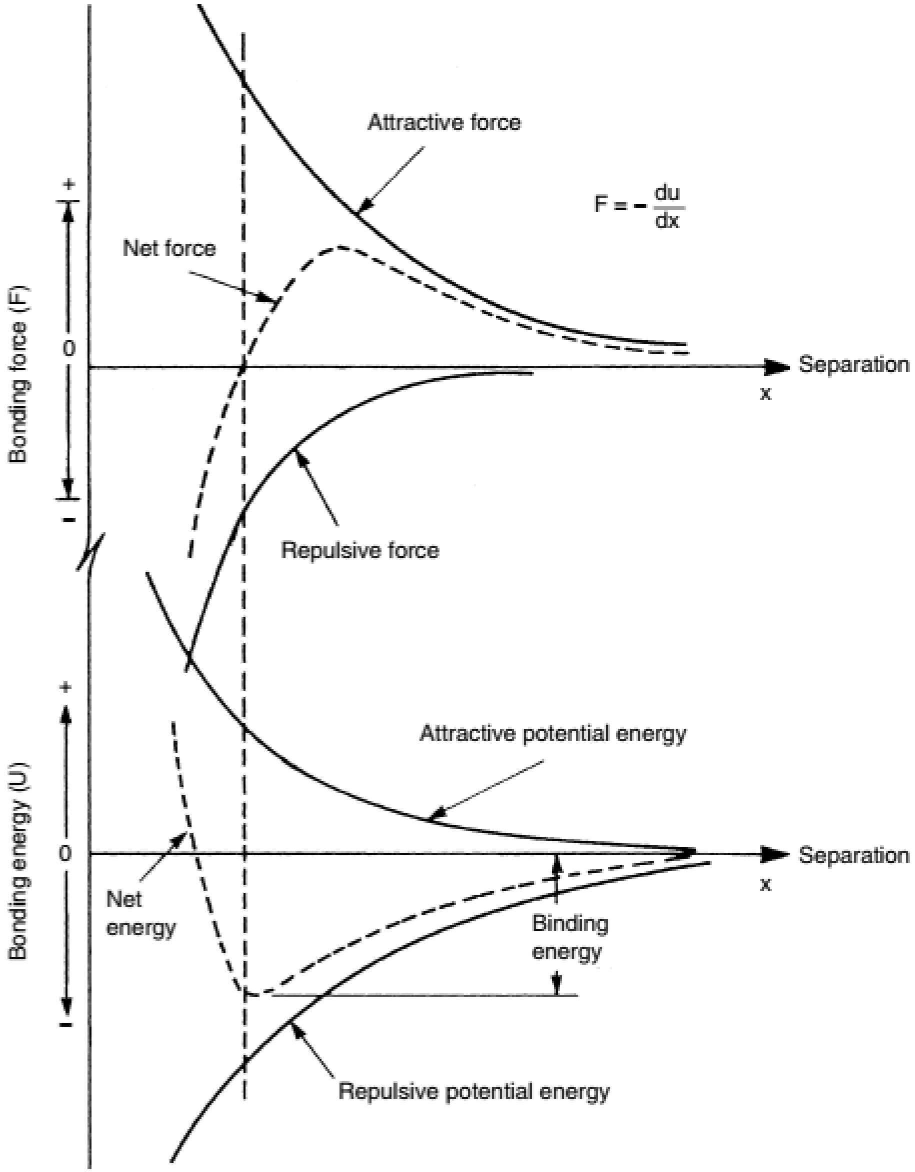
Advantages and disadvantages

Advantages	Disadvantages
Permanent joining	No freedom for disassembly
Large variety of processes	Heat affect
Operation can be automated or manual	Residual stresses
Portability	Need operator skill
Reasonable cost	Criticality involved
Provide leak tight continuous joints	Sophisticated equipment is expensive
Most engineering materials can be joined together	Some combination cannot be joined

Creating a Weld with Atomic-Level Forces







Weld bonding & atomic level forces

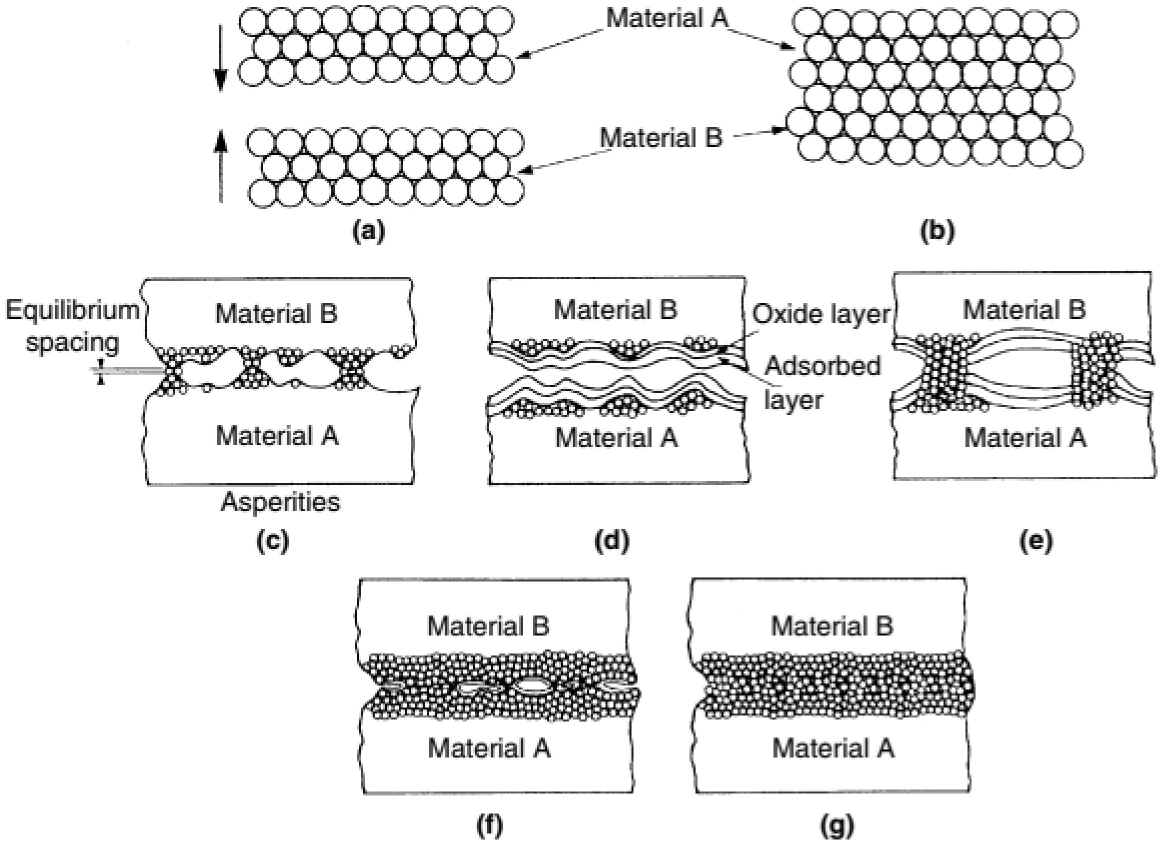


Figure 6.5 Schematic illustration of the formation of welds, as the result of two perfectly smooth and clean ''ideal'' materials versus two real materials. (a) The ideal surfaces before (a) and after (b) being brought into intimate contact (b). The real surfaces (c) that are not atomically smooth and (d) have adsorbed layers and oxides showing disruption of adsorbed layers (e) by heat or pressure and the progressive formation of a weld (f) and (g). (Reprinted from *Joining of Advanced Materials*, Robert W. Messler, Jr., Fig. 6.3, page 185, Butterworth-Heinemann, Stoneham, MA, 1993, with permission of Elsevier Science, Burlington, MA.)

Classification on the basis of Energy source

AWS has developed its own classification of welding processes including brazing, soldering and other allied process.

40 welding processes are recognized by AWS

Fusion and non fusion welding: In fusion welding substrate & filler metal are bring to molten form *while* in non fusion welding melting of the substrate does not occur.

- Pressure and non pressure welding,
- Welding using a filler and without filler welding,
- Based on the heat source,
- Consumable and non-consumable electrodes.

Classification on the basis of Energy source

Table 6.2 Welding Processes Listed by Energy Source

Mechanical	*Chemical*	*Electrical*
Cold Welding (CW)	Pressure Gas Welding (PGW)	Stud Arc Welding (SW)
Hot Pressure Welding (HPW)	Exothermic Pressure Welding	Magnetically Impelled Arc Butt (MIAB) Welding
Forge Welding (FOW)	Pressure Thermit Welding (PTW)	Resistance Spot Welding (RSW)
Roll Welding (ROW)	Forge Welding (FOW)	Resistance Seam Welding (RSEW)
Friction Welding (FRW)	Oxy-Fuel Gas Welding (OFW)	Projection Welding (PW)
Ultrasonic Welding (USW)	Exothermic Welding or Thermit Welding (TW)	Flash Welding (FW)
Friction Stir Welding (FSW)	Transient Liquid Phase Bonding (TLPB)	Upset Welding (UW)
Explosion Welding (EXW)		Percussion Welding (PEW)
Deformation Diffusion Welding (DFW)		Gas-Tungsten Arc Welding (GTAW)
Continuous Seam DFW (CSDFW)		Plasma Arc Welding (PAW)
Creep Isostatic Pressure Welding (CRISP)		Carbon Arc Welding (CAW)
		Atomic Hydrogen Welding (AHW)
		Gas-Metal Arc Welding (GMAW)
		Shielded-Metal Arc Welding (SMAW)
		Flux-Cored Arc Welding (FCAW)
		Submerged Arc Welding (SAW)
		Electrogas Welding (EGW)
		Electroslag Welding (ESW)

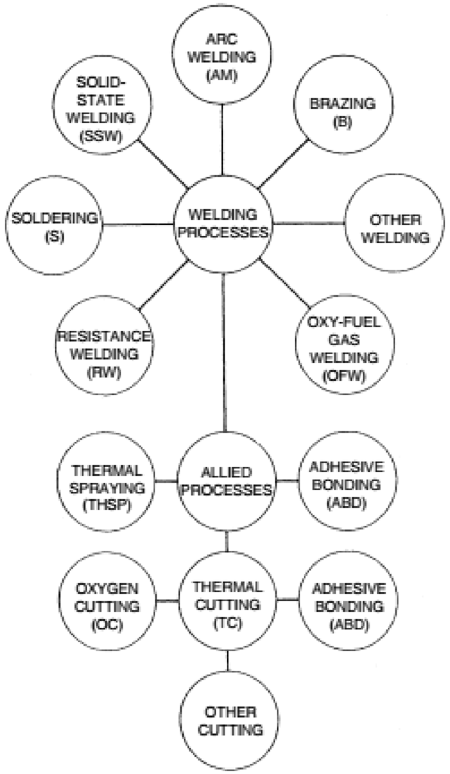
NOTE: Letter designations used are those recommended and standardized by the American Welding Society, Mami, FL.

Classification on the basis of phase reactions

Liquid–solid interface reactions or processes occur at the interface, in which bonds are obtained by epitaxial solidification of a liquid phase in contact with a parent solid phase.

b. Solid–solid interface reactions or processes occur at the interface, in which bonds are obtained from solid-state contact between the parts of the assembly by some means involving pressure and diffusion.

c. Vapor–solid interface reactions or processes occur at the interface, in which material condenses from the vapor state onto a parent phase that remains solid to directly produce a bond (as in surface coating) or assist in the production of bonds (as in some forms of brazing).



(a)

Group	Welding Process	Letter Designation
Arc welding	Carbon arc	CAW
	Electrogas	EGW
	Flux-colored arc	FCAW
	Gas metal arc	GMAW
	Gas tungsten arc	GTAW
	Plasma arc	PAW
	Shielded metal arc	SMAW
	Stud arc	SW
	Submerged arc	SAW
Brazing	Diffusion brazing	DFB
	Dip brazing	DB
	Furnace brazing	IB
	Induction brazing	IRB
	Resistance brazing	RB
	Torch brazing	TB
Oxy-fuel gas welding	Oxyacetylene welding	OAW
	Oxyhydrogen welding	OHW
	Air acetylene	
	Pressure gas welding	PGW
Resistance welding	Flash welding	FW
	Projection welding	DFW
	Resistance seam welding	RSEW
	Resistance spot welding	RSW
	Upset welding	UW
Soild-state welding	Cold welding	CW
	Diffusion welding	DFW
	Explosion welding	EXW
	Forge welding	FOW
	Friction welding	FRW
	Hot pressure welding	HPW
	Roll welding	ROW
	Ultrasonic welding	USW
Soldering	Dip soldering	DS
	Furnace soldering	FS
	Induction soldering	IS
	Infrared soldering	IRS
	Iron soldering	INS
	Resistance soldering	RS
	Torch soldering	TS
	Wave soldering	WS
Other welding processes	Electron beam	EBW
	Electroslag	ESW
	Flow	FLOW
	Induction	IW
	Laser beam	LBW
	Percussion	PEW
	Thermit	TW

(b)

Figure 6.7 The AWS classification of welding and allied processes in a master chart (a), along with a list of processes with their AWS letter designations (b). (Reprinted from *Joining of Advanced Materials*, Robert W. Messler, Jr., Fig. 6.6, page 197, Butterworth-Heinemann, Stoneham, MA, 1993, with permission of Elsevier Science, Burlington, MA and the American Welding Society, Miami, FL.)

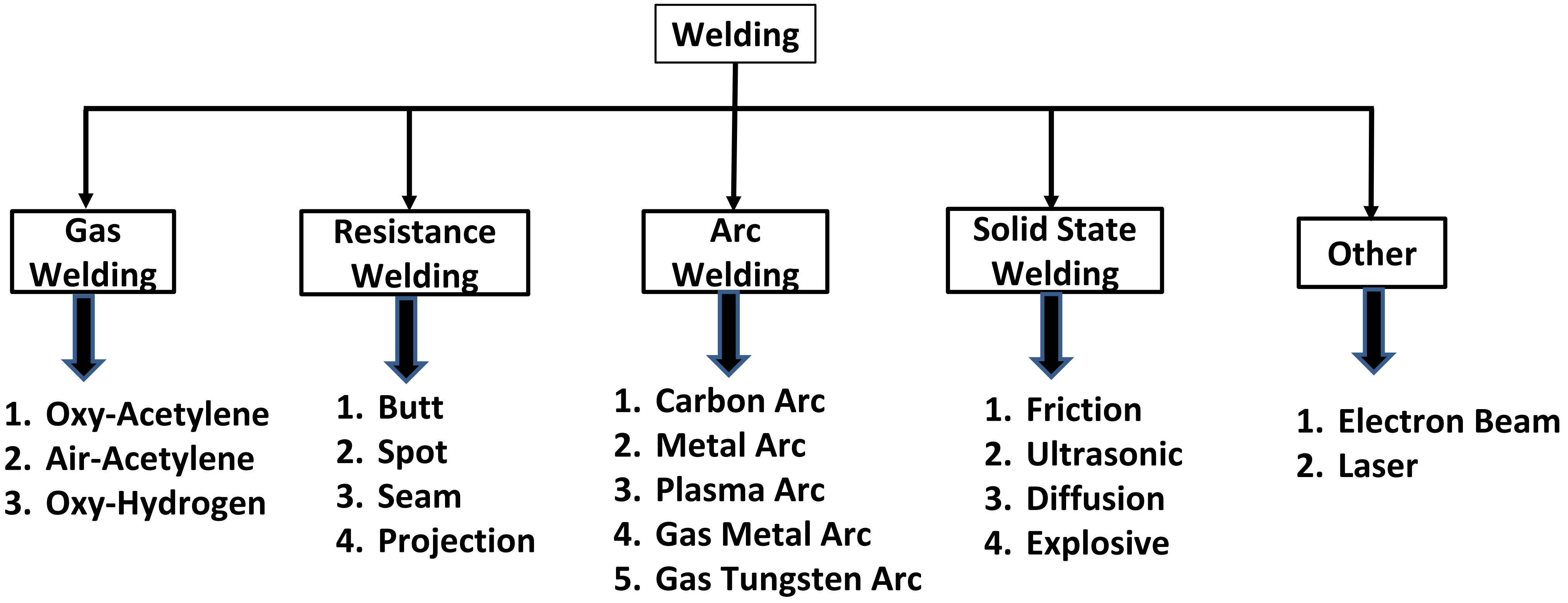
Autogenous Versus Homogeneous Versus Heterogeneous Welding

- In fusion welding , when no filler is required or used, the process is called **autogenous**.

- For autogenous welding to produce structurally sound and attractive welds, the base materials making up the joint must be the same or highly compatible to allow mixing without problems, and the fit of the joint elements must be good.

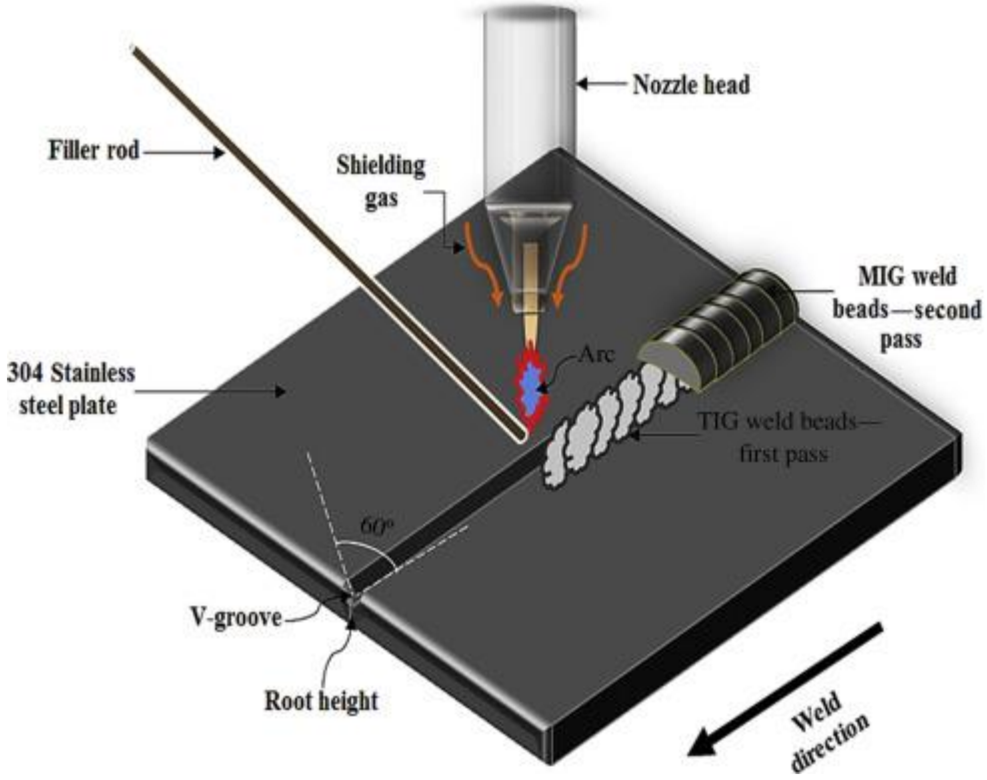
- If filler is required or used, the process is called **homogeneous** if the filler's composition is the same as the base material.

- If the filler's composition is the different as the base material, the welding process is called **heterogenous**.

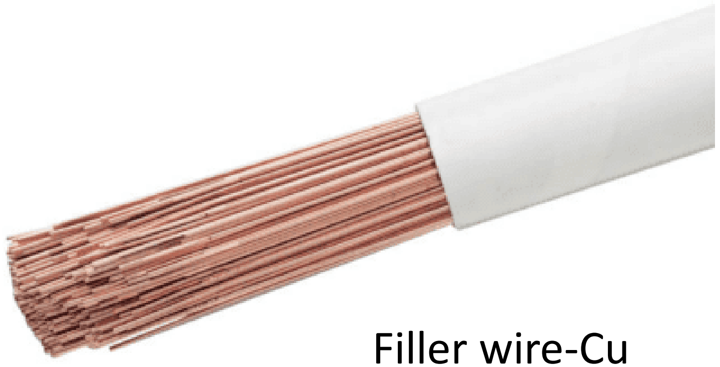

Welding
Gas Welding
Resistance Welding
Arc Welding
Solid State Welding
Other
1. Oxy-Acetylene
2. Air-Acetylene
3. Oxy-Hydrogen
1. Butt
2. Spot
3. Seam
4. Projection
1. Carbon Arc
2. Metal Arc
3. Plasma Arc
4. Gas Metal Arc
5. Gas Tungsten Arc
1. Friction
2. Ultrasonic
3. Diffusion
4. Explosive
1. Electron Beam
2. Laser

Filler Rods in Welding

Filler Rod- Stainless Steel

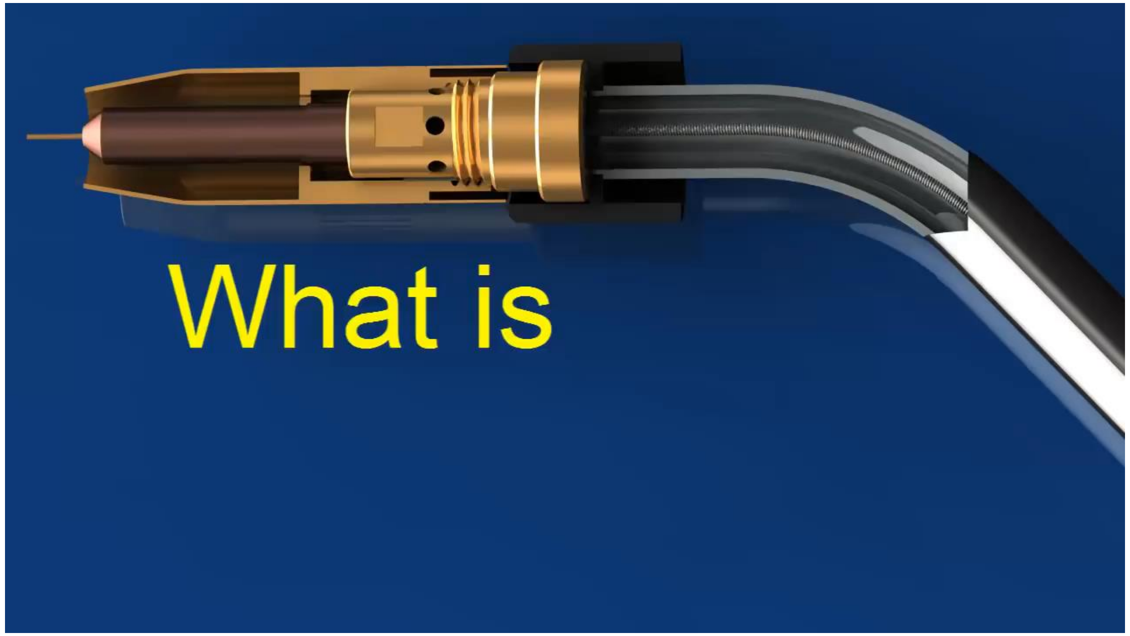


Filler wire- Steel

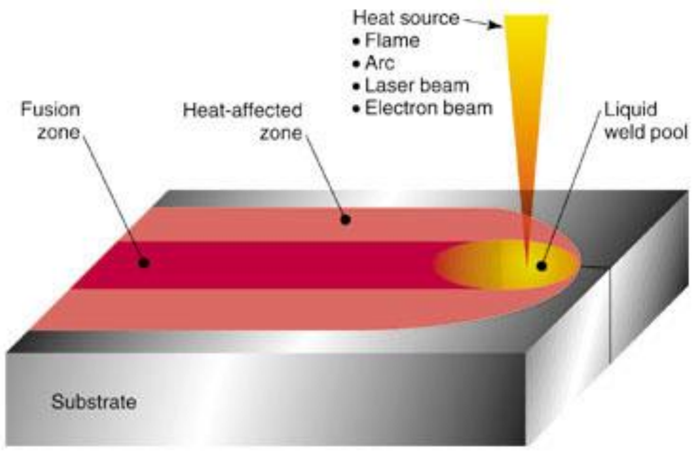


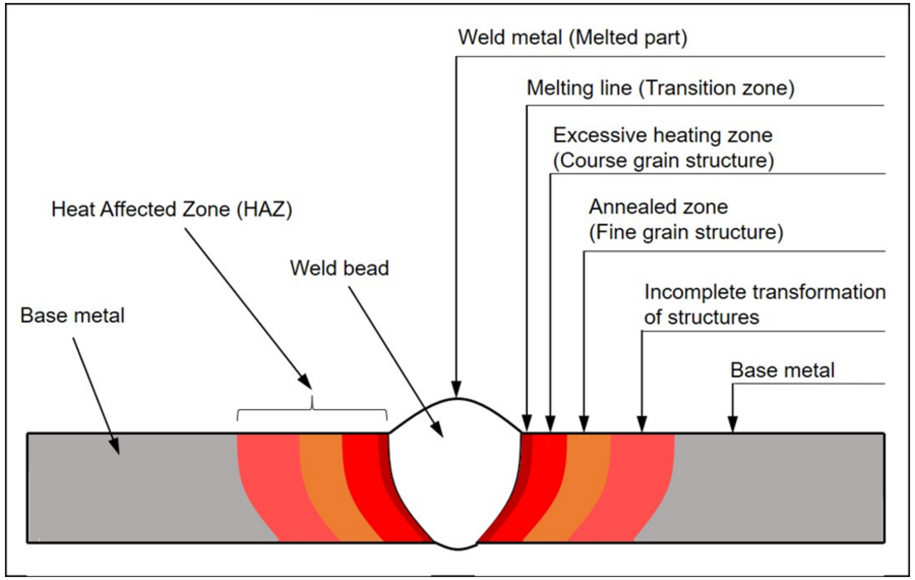
Filler wire-Cu

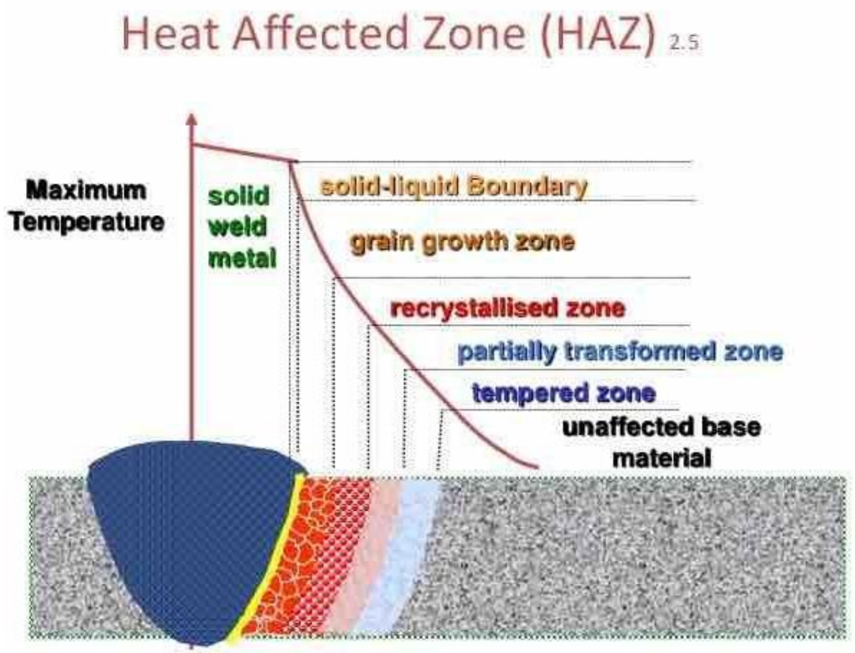
Filler Spool in Welding

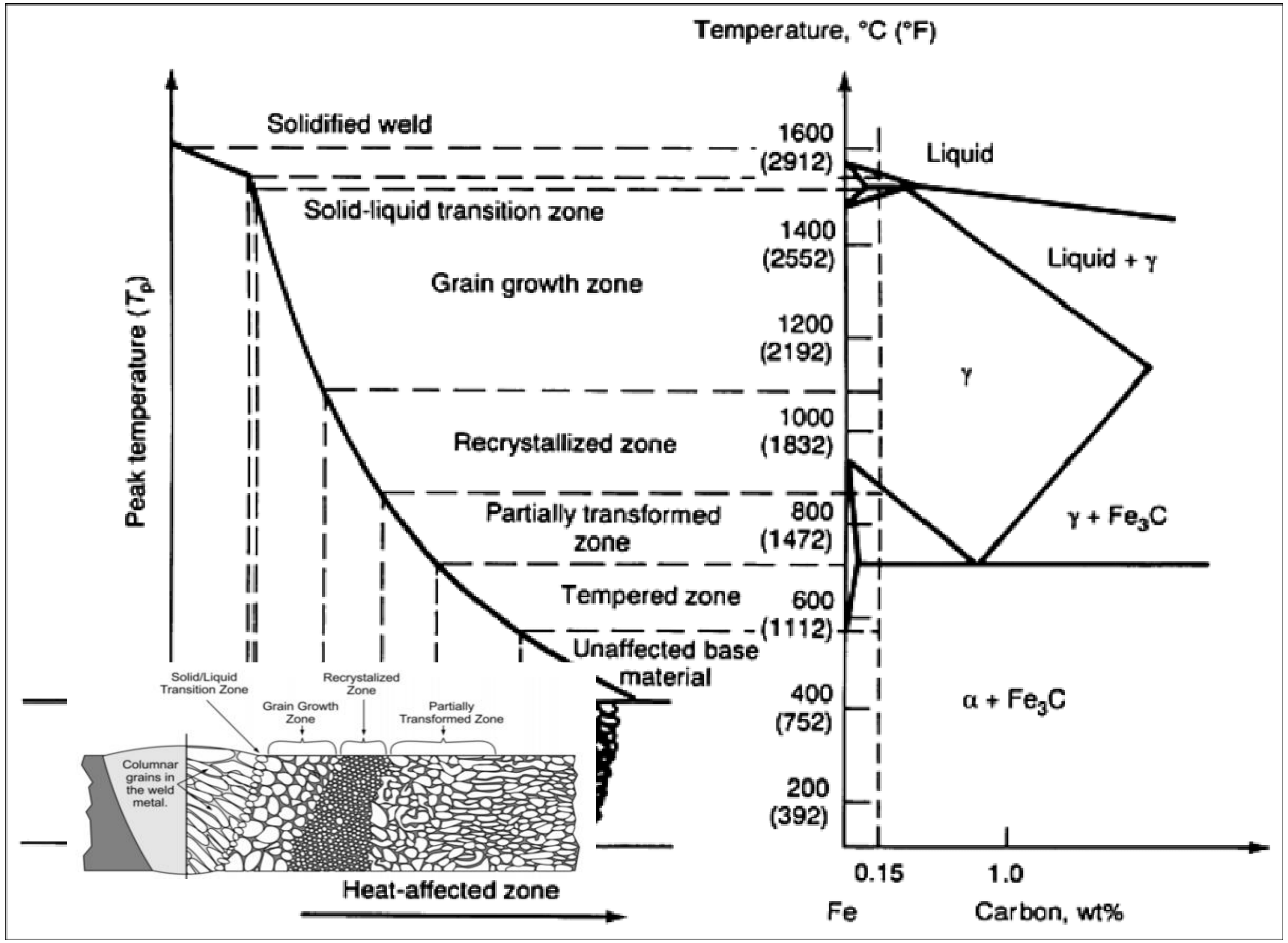


Spools Filler wire


Heat source
• Flame
• Arc
• Laser beam
• Electron beam
Fusion zone
Heat-affected zone
Liquid weld pool
Substrate


Weld metal (Melted part)
Melting line (Transition zone)
Excessive heating zone
(Course grain structure)
Heat Affected Zone (HAZ)
Annealed zone
(Fine grain structure)
Weld bead
Incomplete transformation
of structures
Base metal
Base metal


Heat Affected Zone (HAZ) 2.5
Maximum Temperature
solid weld metal
solid-liquid Boundary
grain growth zone
recrystallised zone
partially transformed zone
tempered zone
unaffected base material



Temperature, °C (°F)
Solidified weld
Solid-liquid transition zone
Grain growth zone
Recrystallized zone
Partially transformed zone
Tempered zone
Unaffected base material
Peak temperature (T_p)
1600 (2912)
1400 (2552)
1200 (2192)
1000 (1832)
800 (1472)
600 (1112)
400 (752)
200 (392)
Liquid
Liquid + γ
γ
γ + Fe_3C
α + Fe_3C
0.15
1.0
Fe
Carbon, wt%
Solid/Liquid Transition Zone
Recrystalized Zone
Grain Growth Zone
Partially Transformed Zone
Columnar grains in the weld metal.
Heat-affected zone

Fusion and Non-Fusion Joint

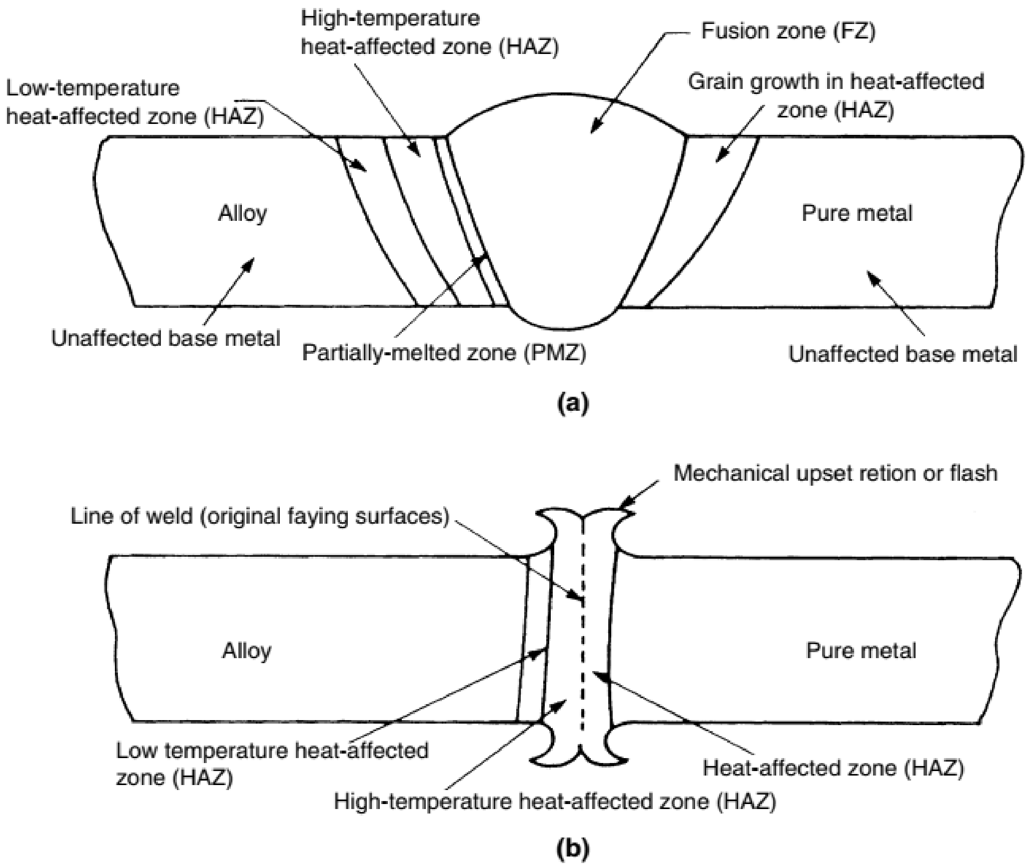
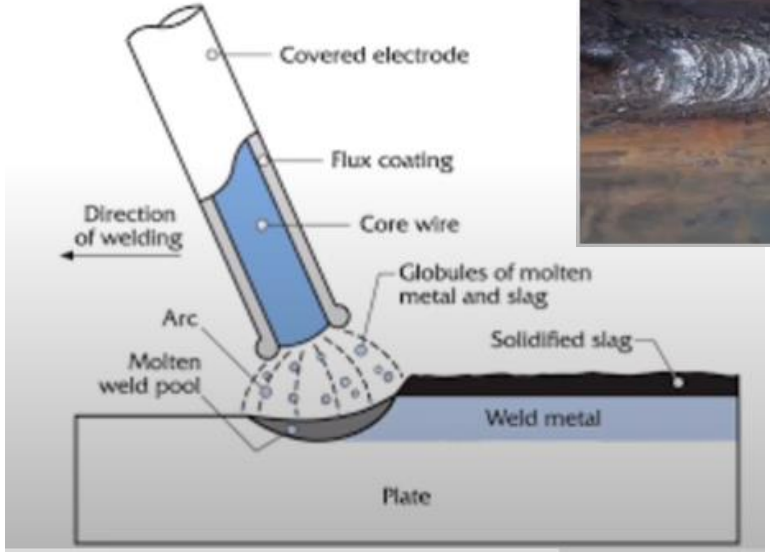
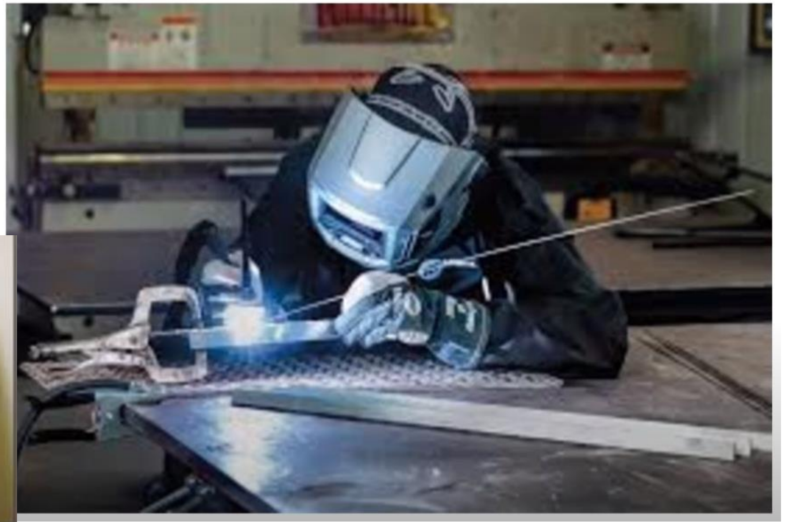


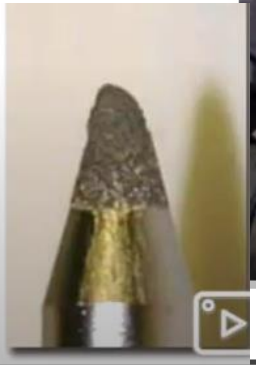
Figure 6.8 Schematic illustration of the various microstructural zones in typical, hypothetical (a) fusion and (b) non-fusion welds. (Reprinted from *Joining of Advanced Materials*, Robert W. Messler, Jr., Fig. 6.5, page 193, Butterworth-Heinemann, Stoneham, MA, 1993, with permission of Elsevier Science, Burlington, MA.)

Non-consumable Versus Consumable Electrode Arc Welding Processes

In electric arc fusion welding processes, the electrode used to strike the arc with the workpiece can serve only as the means for carrying current to the arc and, thereby, heat the substrates, or it may be consumed in the arc to contribute filler as well as heat to the weld. In the first case, the process is referred to as a non-consumable or permanent electrode welding process, while in the second case, the process is referred to as a consumable electrode welding process.







Consumable Electrode Arc Welding Processes

Arc Welding processes that employ a consumable electrode:

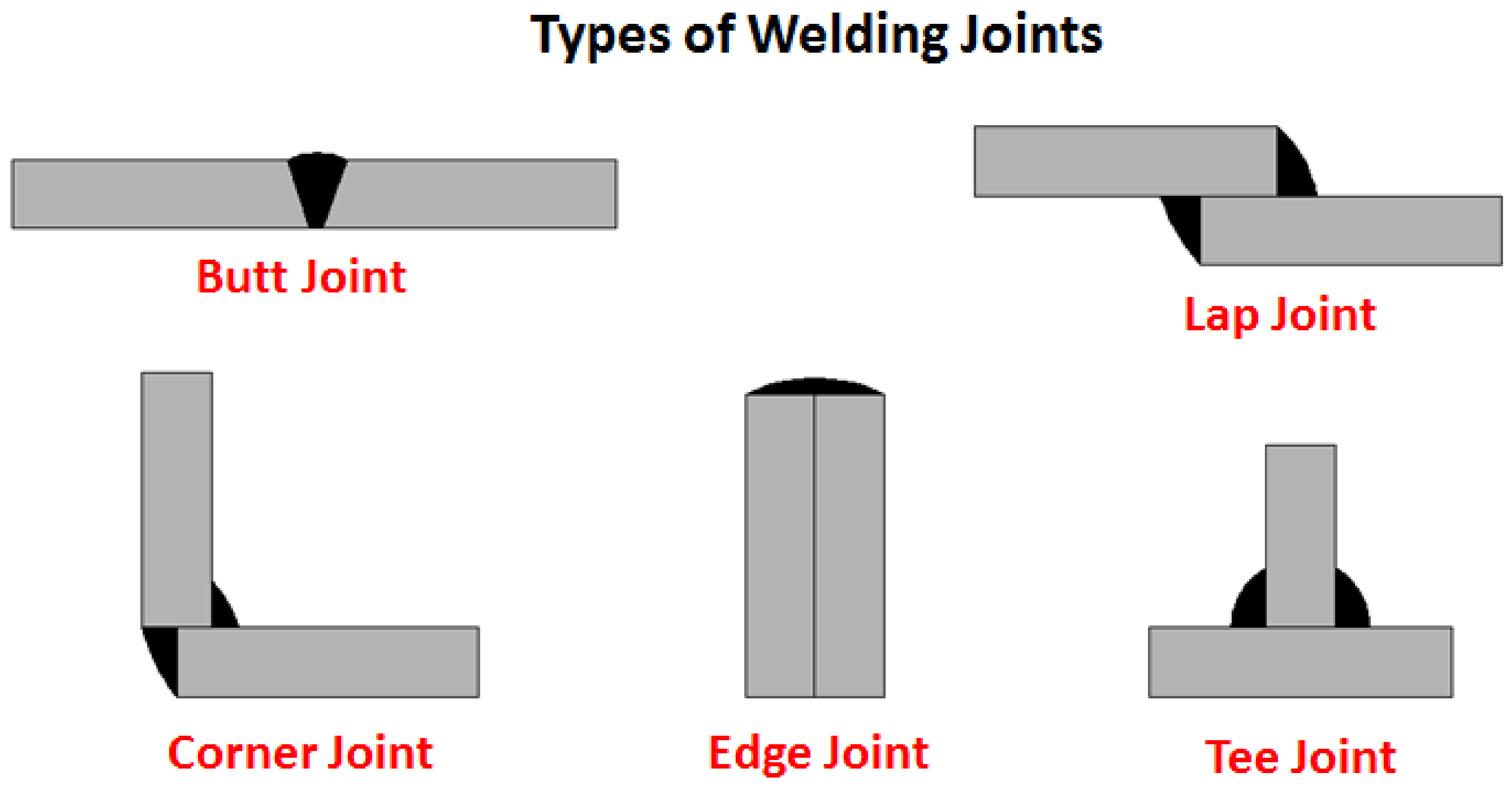
- Shielded Metal arc Welding (SMAW)
- Gas metal Arc Welding (GMAW)
- Flux cored arc welding(FCAW)
- Submerged Arc Welding(SAW)
- Electroslag Welding (ESW)
- Electro-gas Welding (EGW)

Non-consumable Electrode Arc Welding Processes

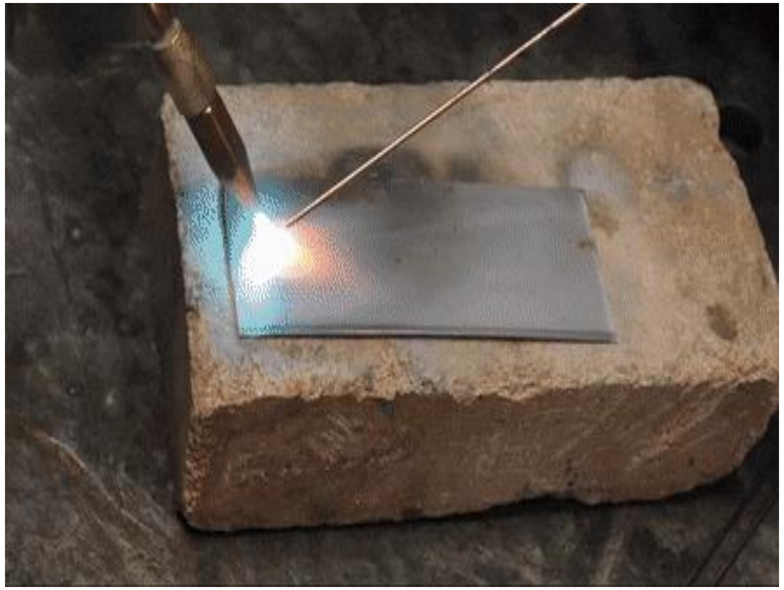
Arc Welding processes that employ a non- consumable electrode:

- Gas Tungsten Arc Welding or Tungsten Inert Gas Welding (TIG)
- Atomic Hydrogen Welding (AHW)
- Carbon Arc Welding (CAW)

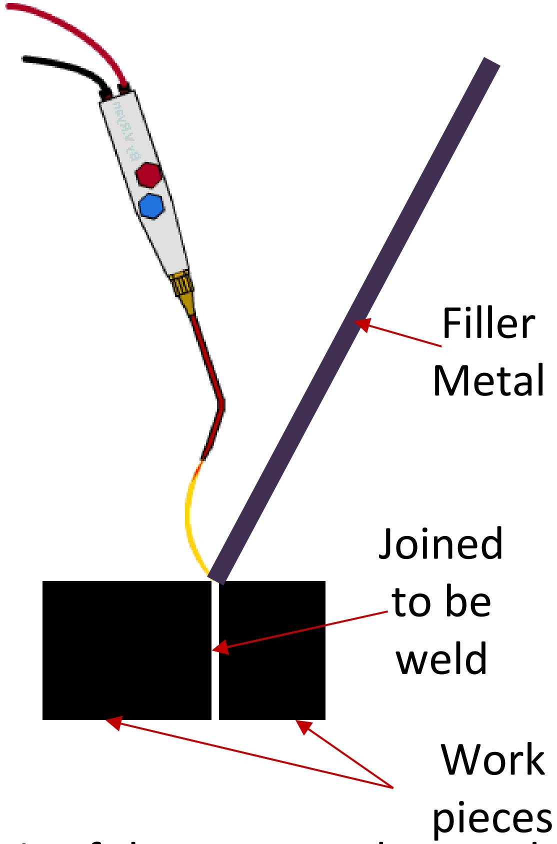
Types of welding joints



Oxy-Acetylene Welding



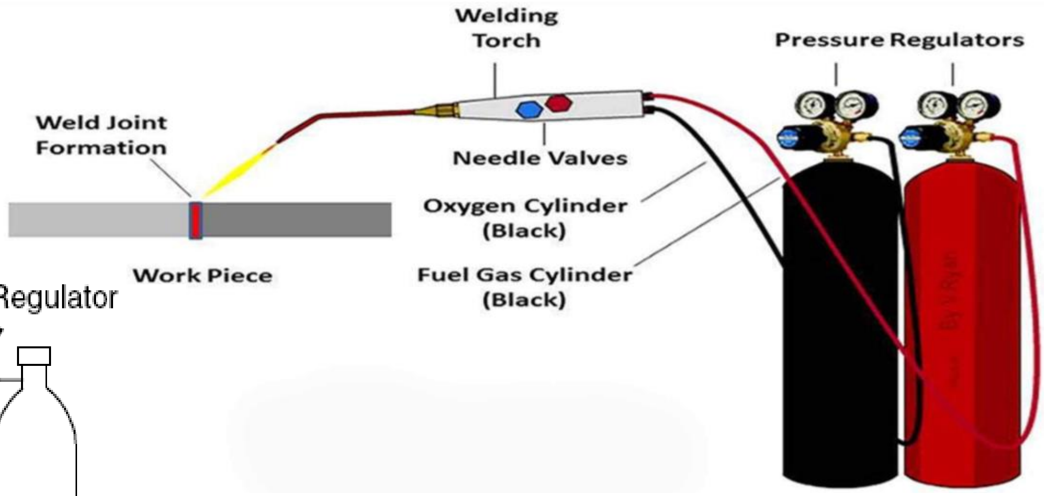
Actual oxy-acetylene welding process.

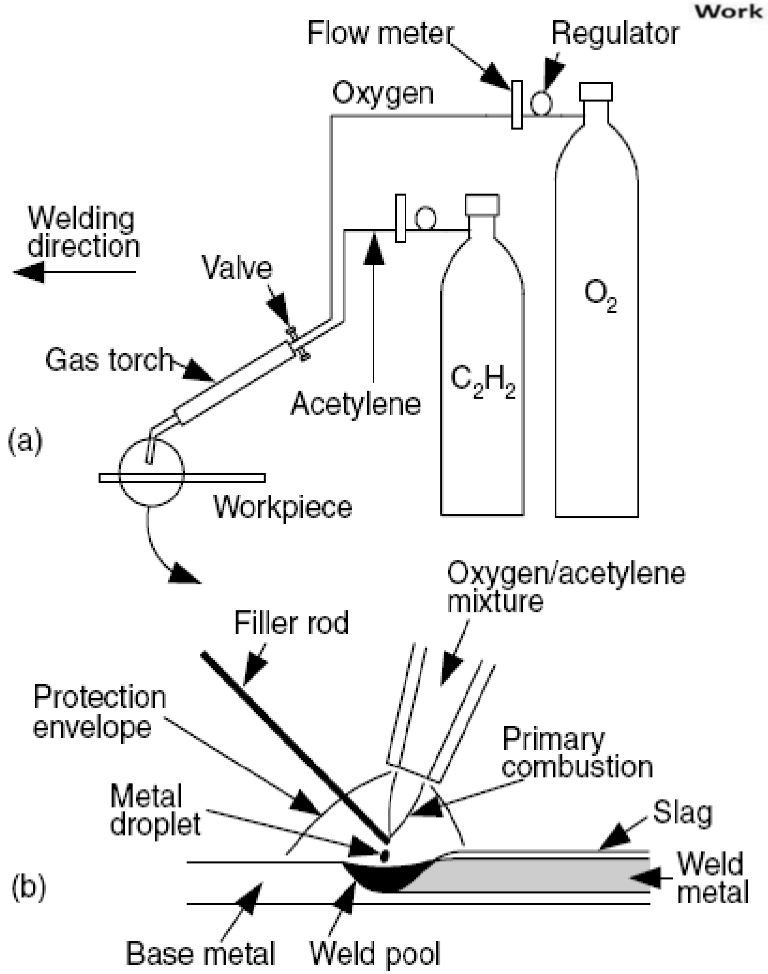


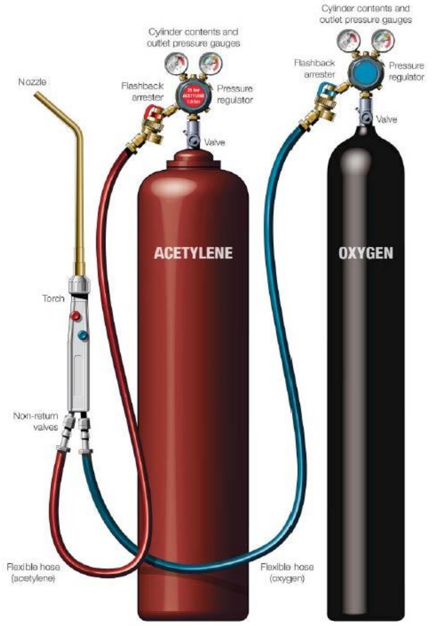
Schematic of the oxy-acetylene welding process

Oxy-Acetylene Welding

Natural gas, MAPP gas, propane, butane, and other hydrocarbon gases (or even hydrogen) can be used.







Oxy-Acetylene Welding

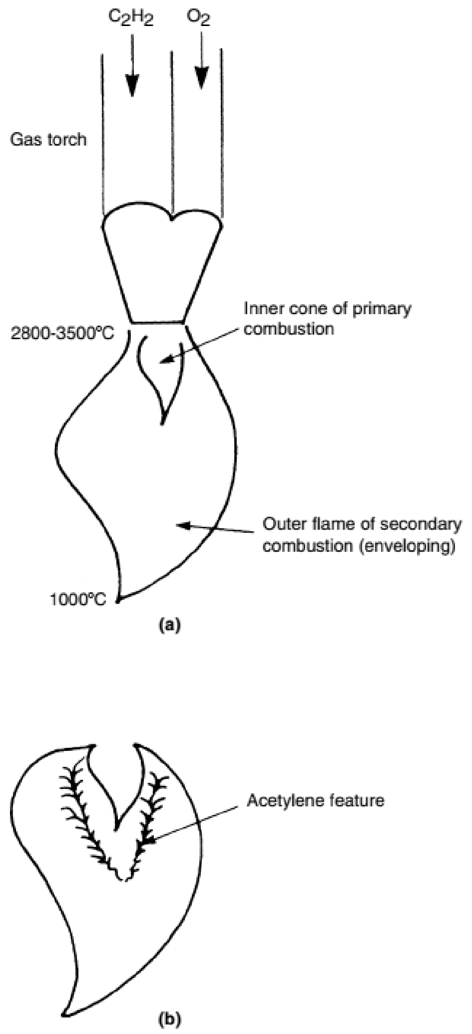
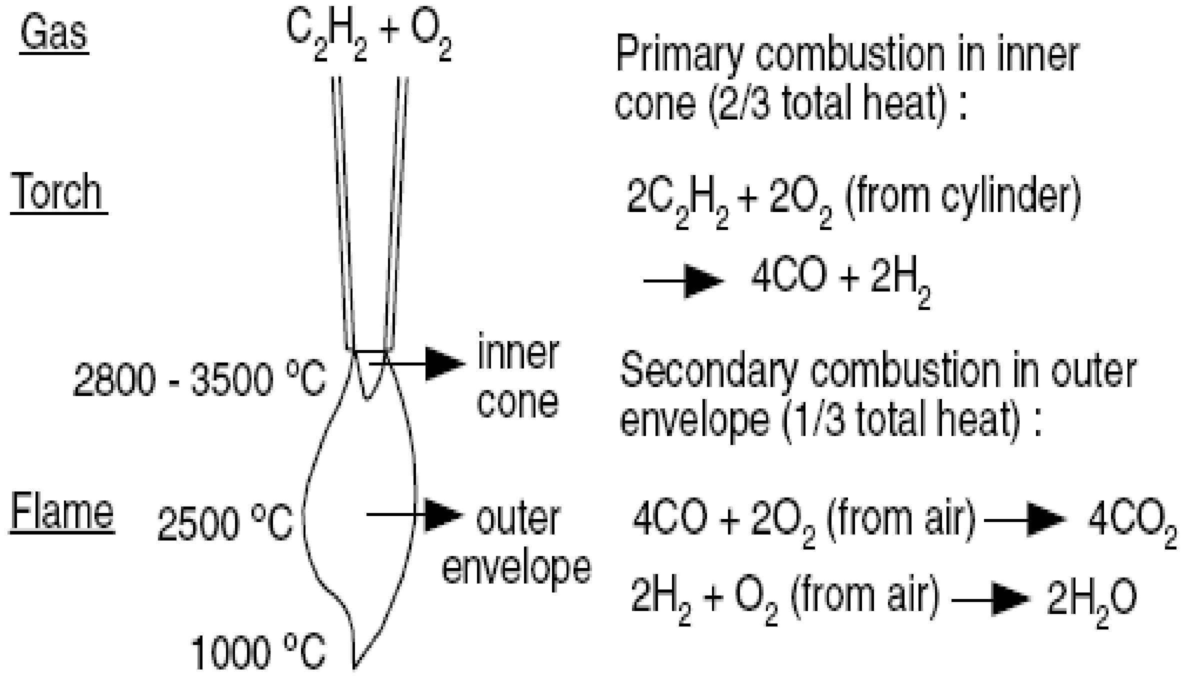
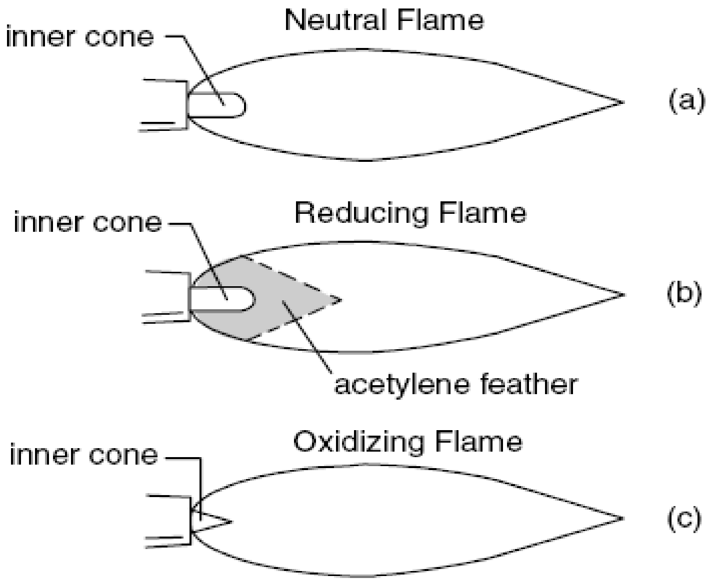


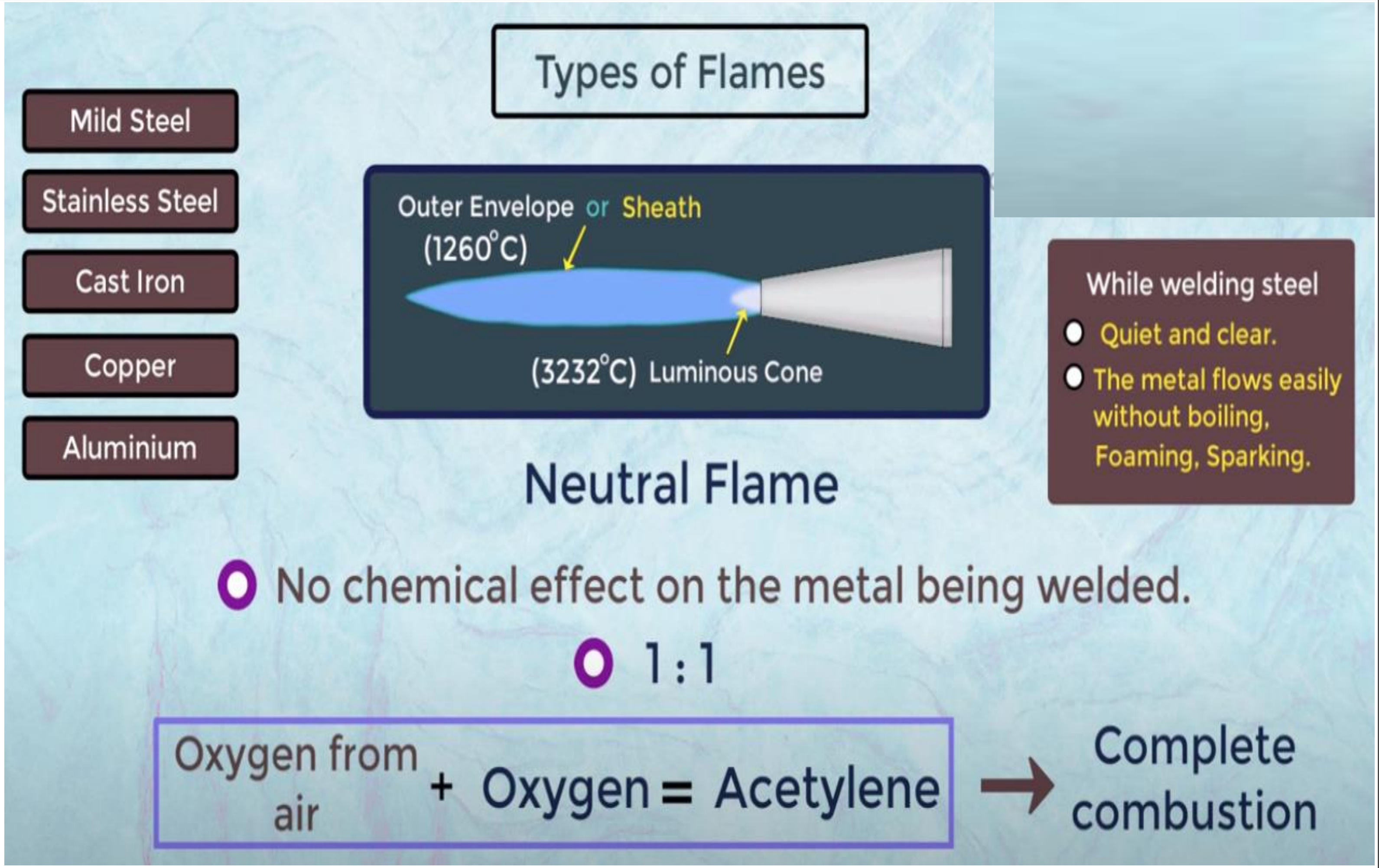
Figure 6.9 Schematic of a typical oxy-fuel gas flame used in welding and cutting; here, showing an oxyacetylene flame adjusted to be neutral (a) and reducing (b). The primary and secondary regions of combustion are shown in (a), while the acetylene "feather" characteristic of a reducing flame is shown in (b). (Reprinted from *Joining of Advanced Materials*, Robert W. Messler, Jr., Fig. 6.7, page 199, Butterworth-Heinemann, Stoneham, MA, 1993, with permission of Elsevier Science, Burlington, MA.)

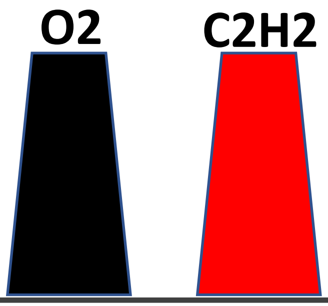


Oxy-Acetylene Welding

Types of flames

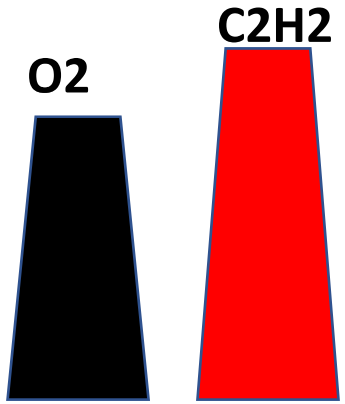


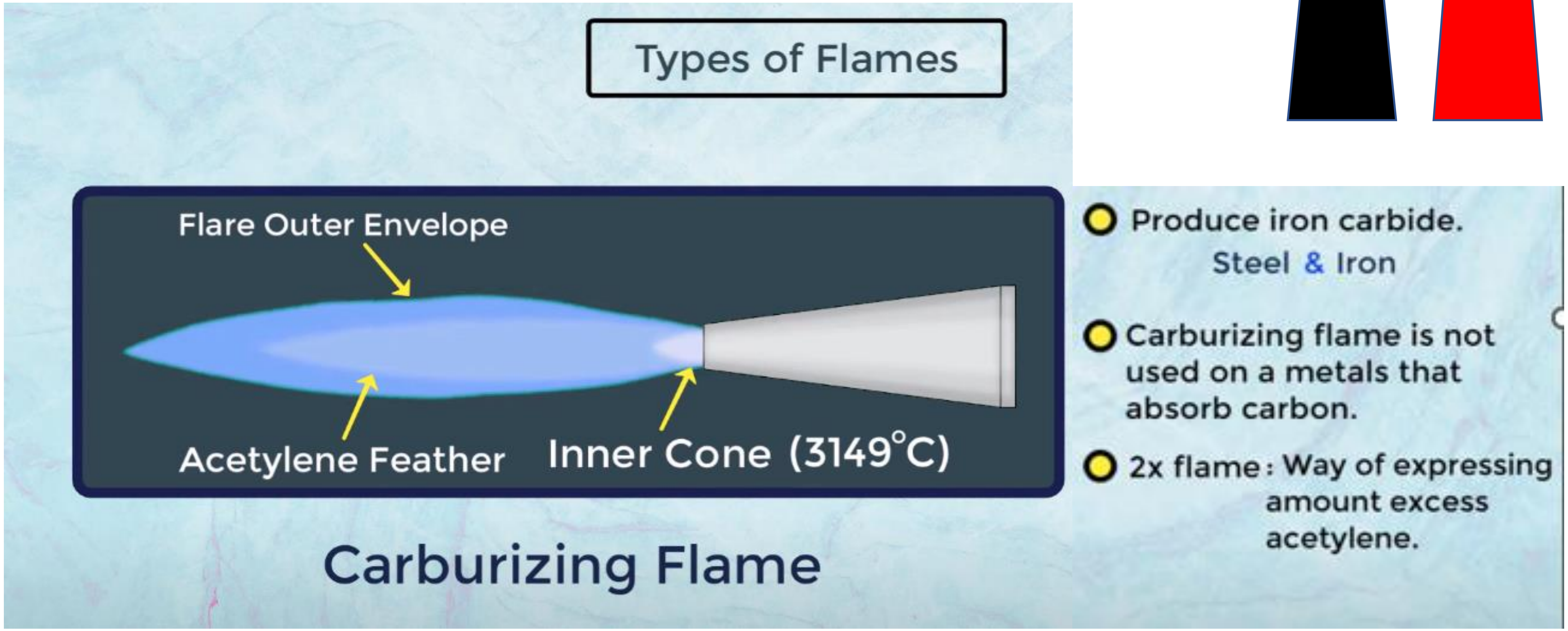




Oxy-Acetylene Welding

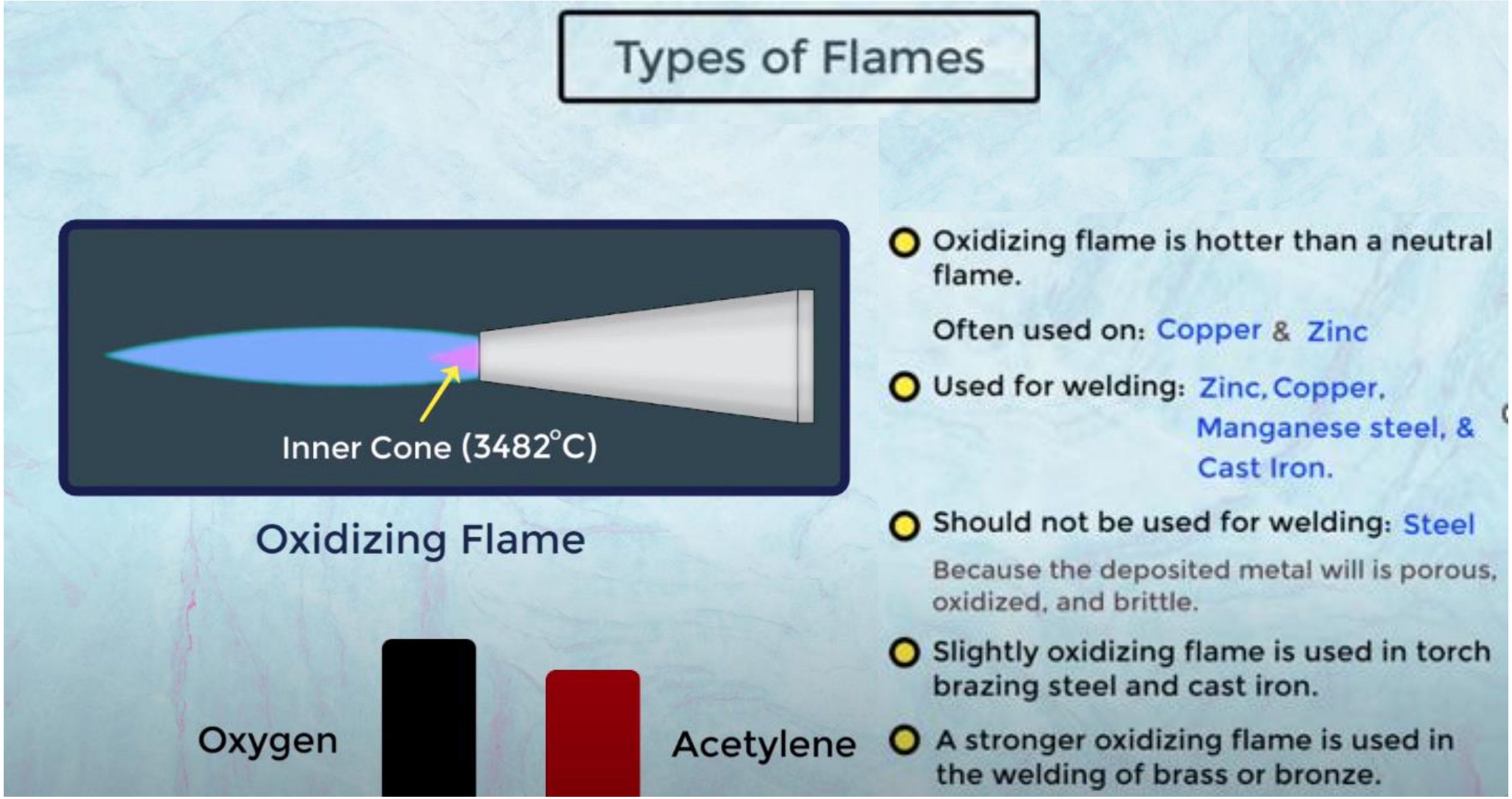
Types of flames





Oxy-Acetylene Welding

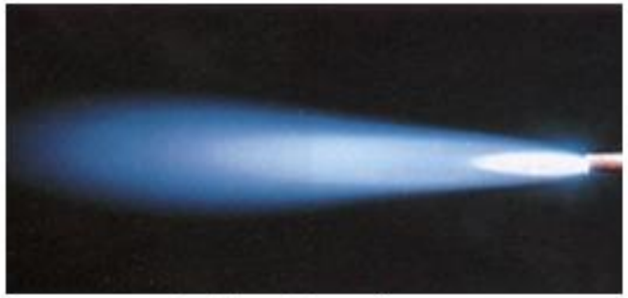
Types of flames

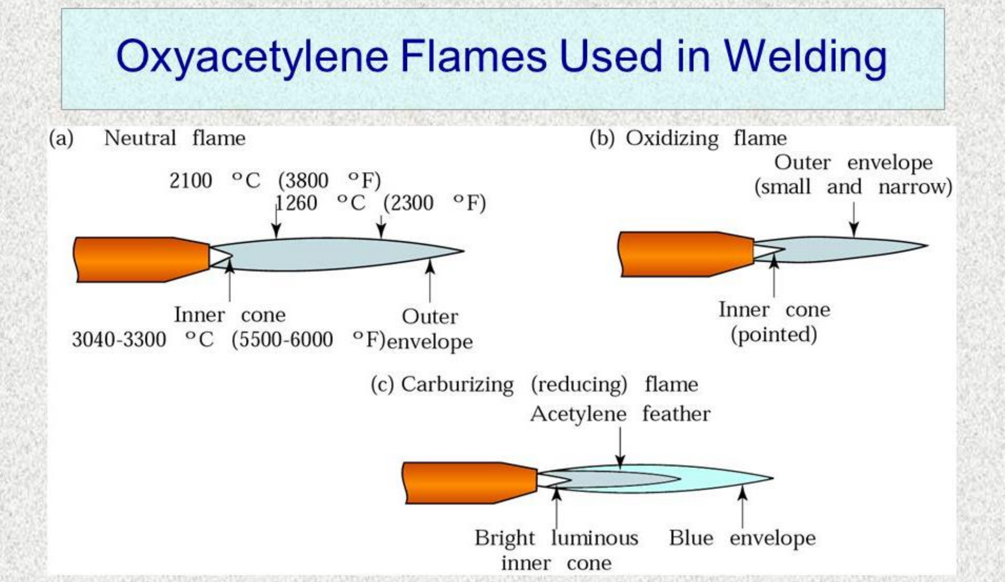


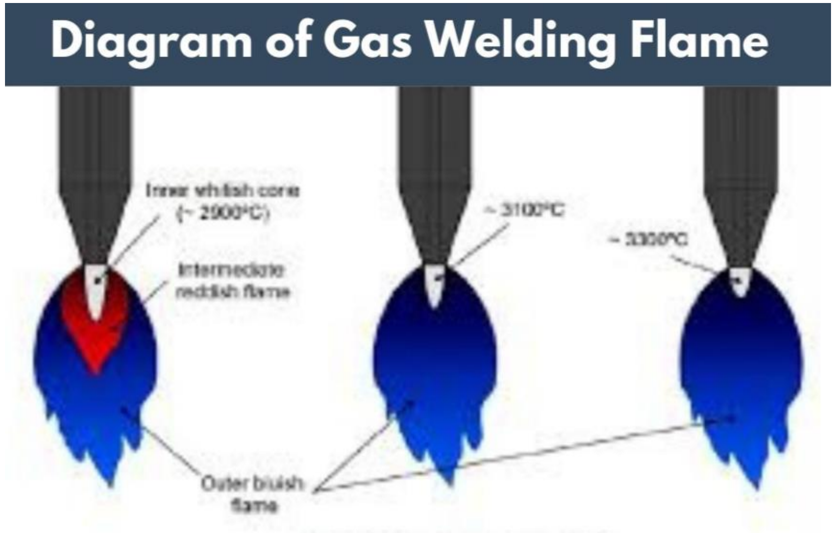
Oxy-Acetylene Welding


Neutral flame


Oxidising flame


Carburising flame





Oxy-Acetylene Welding

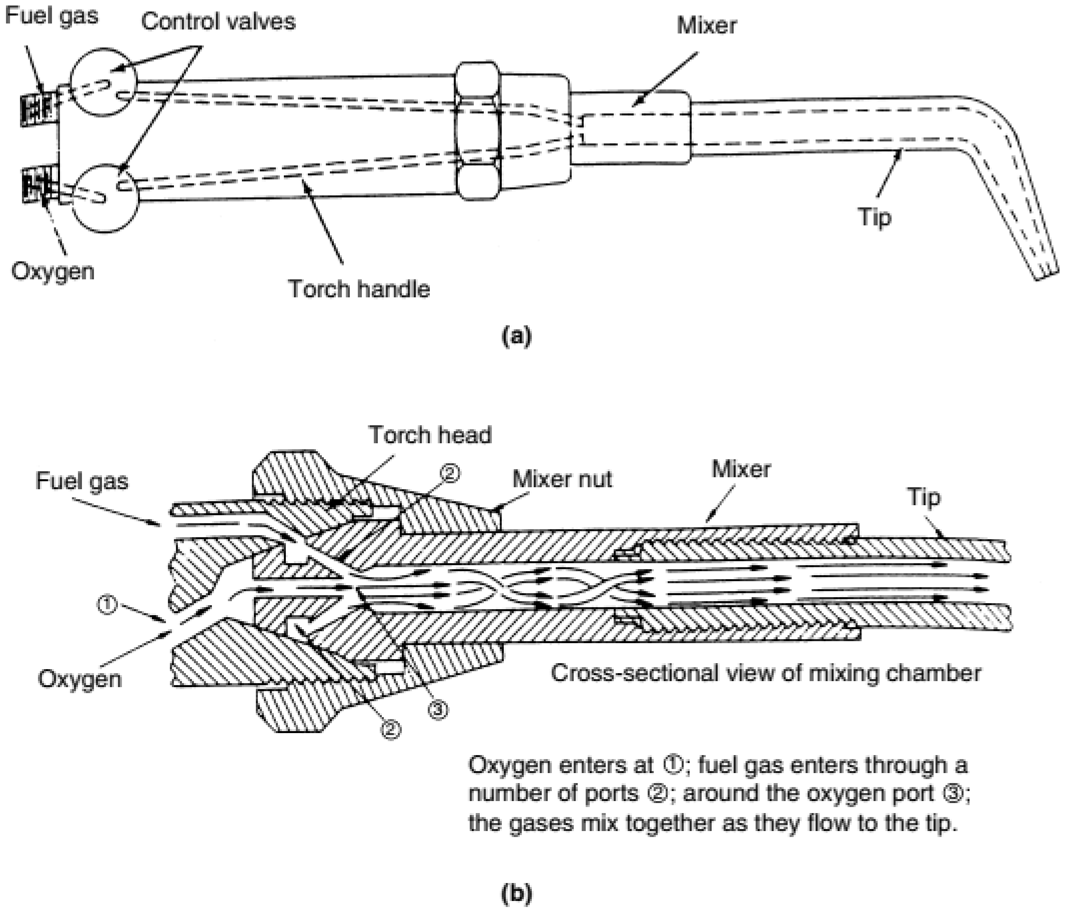


Figure 6.10 Schematic illustration showing (a) the basic elements of an oxy-fuel gas torch and (b) details of the gas mixer for a positive-pressure type torch. (Reprinted from *Joining of Advanced Materials*, Robert W. Messler, Jr., Fig. 6.8, page 200, Butterworth-Heinemann, Stoneham, MA, 1993, with permission of Elsevier Science, Burlington, MA, and the American Welding Society, Miami, FL.)

Oxy-Acetylene Welding

Operating characteristics